U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Transient Fuel Testing R&D (IRP-NE-1)

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Transient Fuel Testing R&D

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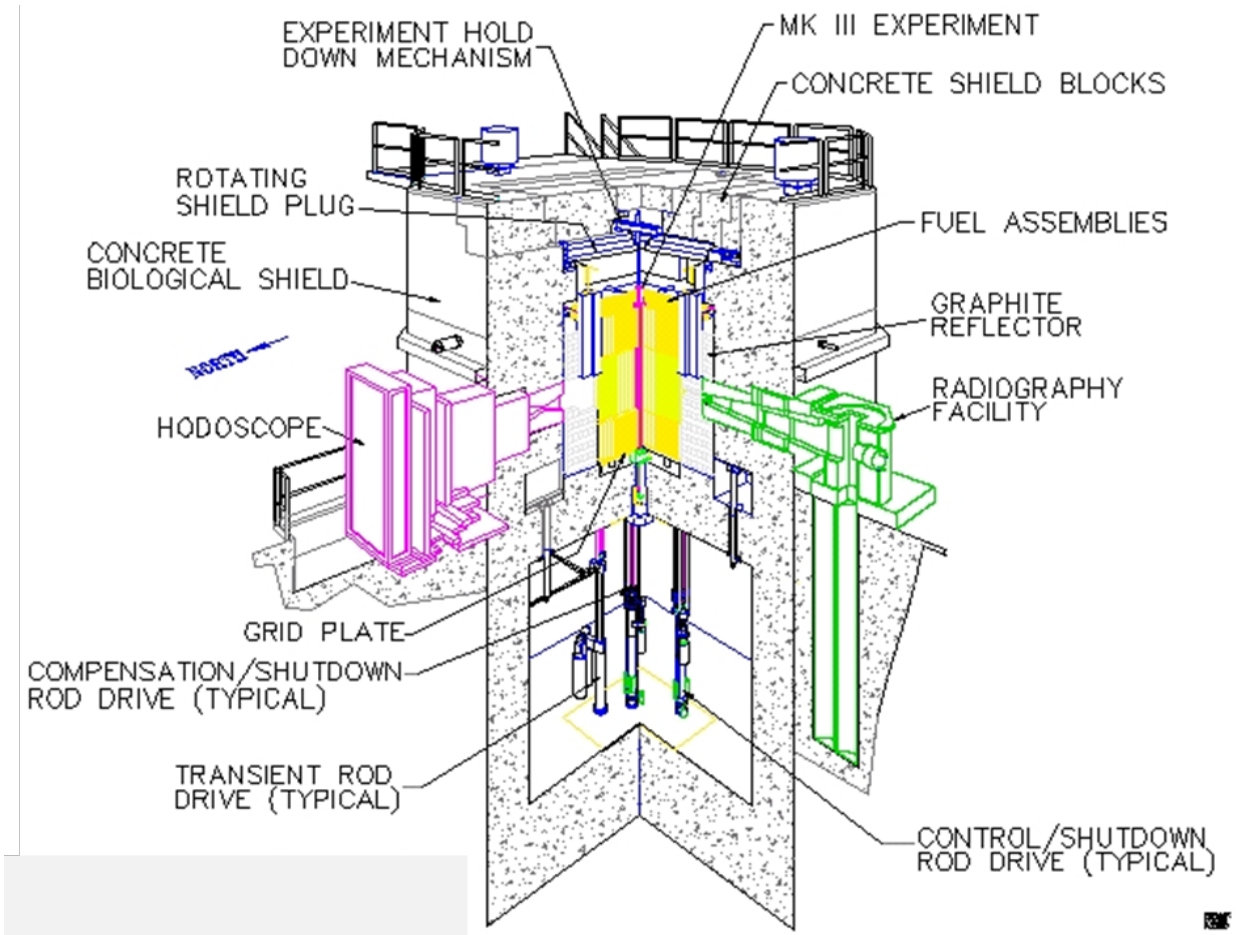
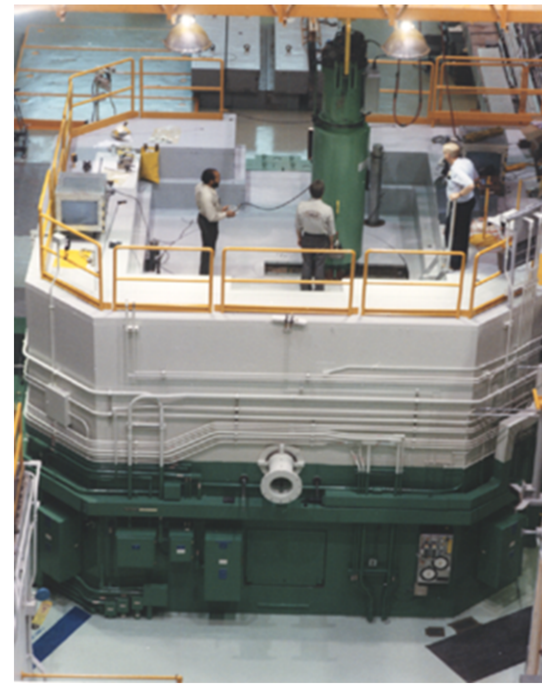
Transient Reactor Test (TREAT) Facility

- TREAT was designed for transient testing of nuclear fuels and materials under off-normal and accident conditions
- Used in performing >800 experiments from 1959 to 1994 (many simple tests, fewer complex tests)
- Supported development and licensing of LWRs and liquid-metal-cooled reactors (LMRs)

TREAT is being restarted to restore transient testing capability: Understand and support licensing of advanced fuels for LWRs such as Accident-Tolerant Fuels and fast-reactor transmutation fuels

Transient Reactor Test (TREAT) Facility





TREAT history

- Early 1960s – Basic-phenomena tests for LWR and SFR safety
  - Hundreds of tests in the early 1960s in simple capsules
  - Most with fresh ceramic (LWR, SFR) and metallic fuels (SFR) fuels
  - Most in inert gas or stagnant coolant
  - Helped resolve key issues – fuel-coolant energetics, and fuel failure criteria
  - Tests on LWR source term
- Mid-1960s to 1994 - SFR tests on metal and oxide fuel (some tests on carbide and nitride)
  - Sodium loop development (1960s and 1970s)
  - Single-pin and multiple-pin tests
  - Specific severe accident issues
  - Qualification of improved fuel designs for irradiation in EBR-II and FFTF
  - Code validation data for CRBR and UK commercial fast reactor licensing
- Mid-1980s - Additional tests on LWR source term
- Mid-1980s to 1994 - SFR metallic fuel tests on post-failure fuel motion during overpower transient

Types of test vehicles for TREAT tests

- **Stagnant Capsules**
  - Dry (inert-gas-filled) or wet (filled with stagnant liquid coolant)
  - phenomenological, separate-effects, basic-process tests

- **Flowing-coolant loops**
  - prototypic, multiple-effects, complex interaction tests

Applications	Experiment Loops	Experiment Capsules
Sodium-cooled reactors	Sodium	Dry or Sodium-filled
Water-cooled reactors	Steam	Water
Gas-cooled reactors	Helium	(none fully designed)

Improved computational models to support transient fuel testing in TREAT

- **Modern modeling tools can:**
  - Improve pre-test analytical design of experiments;
  - Help qualify reactor/test vehicle configuration;
  - Reduce the number of calibration experiments.

- **We need accurate TREAT reactor benchmark cases to validate such codes**
  - Benchmarks will initially be based on existing experimental TREAT data;
  - After restart, benchmarks would incorporate new experimental TREAT data in pulsed mode, including spatial and temporal distribution of temperature and radiation fields;
  - An important role for TREAT is to obtain separate-effects data for validation of fuel models such as BISON/MARMOT.

IRP: Benchmark Evaluations to Support TREAT Modeling and Validation

- **DOE is seeking applications that will develop evaluated benchmark cases to use in the validation of TREAT modeling and simulation codes**
  - Benchmarks will be used to support development and validation of NEAMS and other modern modeling tools;
  - Key data types to include are temperature and radiation field distributions across the core over a timeframe characteristic to the transient;
  - Experimental data from existing TREAT experiments and new data using the prototype water loop now under development at INL.
- **IRP scope contains 3 major tasks:**
  1. Neutronics benchmarks
  2. Loop thermal-hydraulics
  3. Core instrumentation

Task 1: Neutronics Benchmarks (1)

- **Evaluate existing TREAT neutronics calibration data - in accordance with International Handbook of Evaluated Reactor Physics Benchmark Experiments (IRPhEP Handbook)**
  - Requires detailed description of the experiment and measured data;
  - Comprehensive evaluation of experiment parameters, including assessment of unavailable information;
  - Benchmark specifications;
  - Address known simplification biases;
  - Best-estimate calculations, using contemporary nuclear codes and empirical data, to demonstrate adequacy in evaluating experimental data, uncertainties, and biases.
- **Benchmarks will subsequently be available for code validation purposes**

Task 1: Neutronics Benchmarks (2)

- **Task 1a: Steady-State Benchmark(s)**
  - This involves evaluation of existing experimental data of various kinds;
  - Internal and independent reviews of evaluation report(s);
  - Submit to IRPhEP in the first year of this IRP;
  - Prepare final report(s) for handbook publication taking into account feedback from the IRPhEP community.

- **Task 1b: Transient Benchmark(s)**
  - We ask you to investigate available transient TREAT data to establish possible benchmark-usable measurements and develop initial benchmark;
  - Investigate wide range of configurations including delayed and prompt critical transients as well as temperature-limited and shaped transients;
  - Perform analyses with 3D neutron kinetics codes that account for temperature reactivity feedback;
  - In second year of this IRP, submit reviewed benchmark report(s) through IRPhEP to address development of the report format.

Task 2: Loop Thermal-Hydraulics (1)

- **Need loop systems with sodium or water coolant for future tests**
  - For Na, there is an existing recirculating sodium loop design;
  - For water, a completely new water loop is being designed based on same principles as the Na loop

- **Task 2a: Na Loop T-H Benchmark**
  - Use existing data from operation of Na test loops during previous TREAT calibration runs (i.e. M8-CAL and RFT-CAL tests) for benchmark development;
  - Include loop configuration, coolant flow rates, time-dependent coolant temperature distributions, integrated energy deposition profiles, and time dependent energy deposition (via hodoscope outputs);
  - Use appropriate modeling and simulation tools to validate data that represent conditions observed in flow loops.

Task 2: Loop Thermal-Hydraulics (2)

Task 2b: Water Loop T-H Benchmark

- A new, functional prototype water loop to simulate PWR conditions will be fabricated and installed as part of this IRP;
- Loop will be based on conceptual design developed by INL (initiated in FY14 and to be completed in FY15); loop will include electrical heating to simulate fuel pin power;
- Proposal will include enhancements that address final detailed design and instrumentation as-required for fabrication; detailed information and INL technical support will be available to awardee;
- Data needed for this benchmark: configuration, flow rates, pressure, time-dependent temperature distributions, and multi-phase flow parameters;
- Perform operations tests to determine optimal loop control parameters, experiment environment, and the potential for running tests at steady state and loss-of-flow/loss-of-coolant thermal hydraulics conditions;
- Test results will be validated against analyses using appropriate modeling and simulation tools.

Task 3: Core Instrumentation

- **Selection and placement of instrumentation**
  - Identify measurement and instrumentation necessary to develop benchmark-quality transient-testing data;
  - Develop strategy for instrumentation selection and experiments to determine optimal placement of additional instrumentation;
  - Ultimate goal is enhancing operational activities and simulation strategies.

- **Initial benchmark evaluation**
  - Initial analytical evaluation, in advance of actual experimentation, to support planning for benchmark data collection;
  - Initial analyses also serve to develop template for final benchmark report after TREAT has been restarted and sufficient new transient measurements have been obtained for a complete benchmark evaluation;
  - Uncertainty analysis to identify priority core physics data needs to improve core simulation.

Contact Information

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- **For more information regarding resumption of transient testing:**
  - http://energy.gov/ne/articles/resumption-transient-testing

Questions?